LVIS IceBridge Greenland and Antarctica Data

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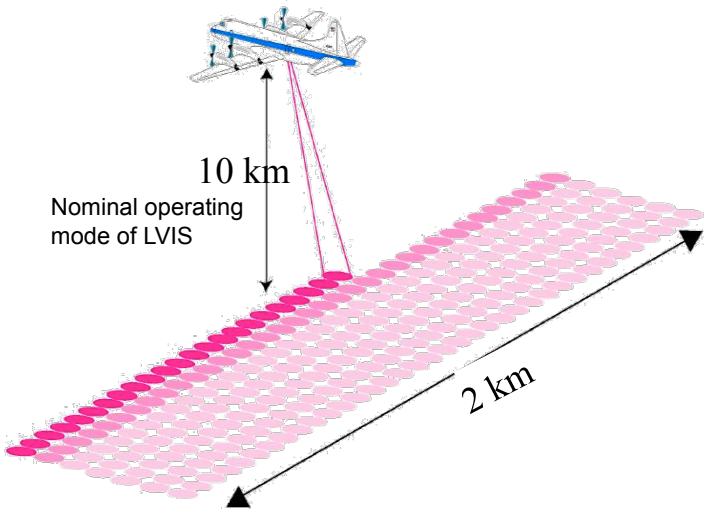
NASA's Land, Vegetation and Ice Sensor (LVIS)

- **NASA's Land, Vegetation and Ice Sensor (LVIS) is a medium-altitude (10km), medium-footprint (5-25m) Waveform-Digitizing Lidar.**
  - Measures surface topography and topographic extent (e.g., crevasse depth), and structure for *every* footprint.
  - Digitally records the shape of each outgoing and returning laser pulse (waveform).
  - Nominal mode: 20m footprint/2km swath from 10km above ground.
  - 500-5,000 Hz laser repetition rate.
  - 1064nm wavelength, 8 ns (FWHM) laser pulse.
  - Nadir-stabilization maximizes coverage.

Sensor installed in NOAA Cessna Citation II

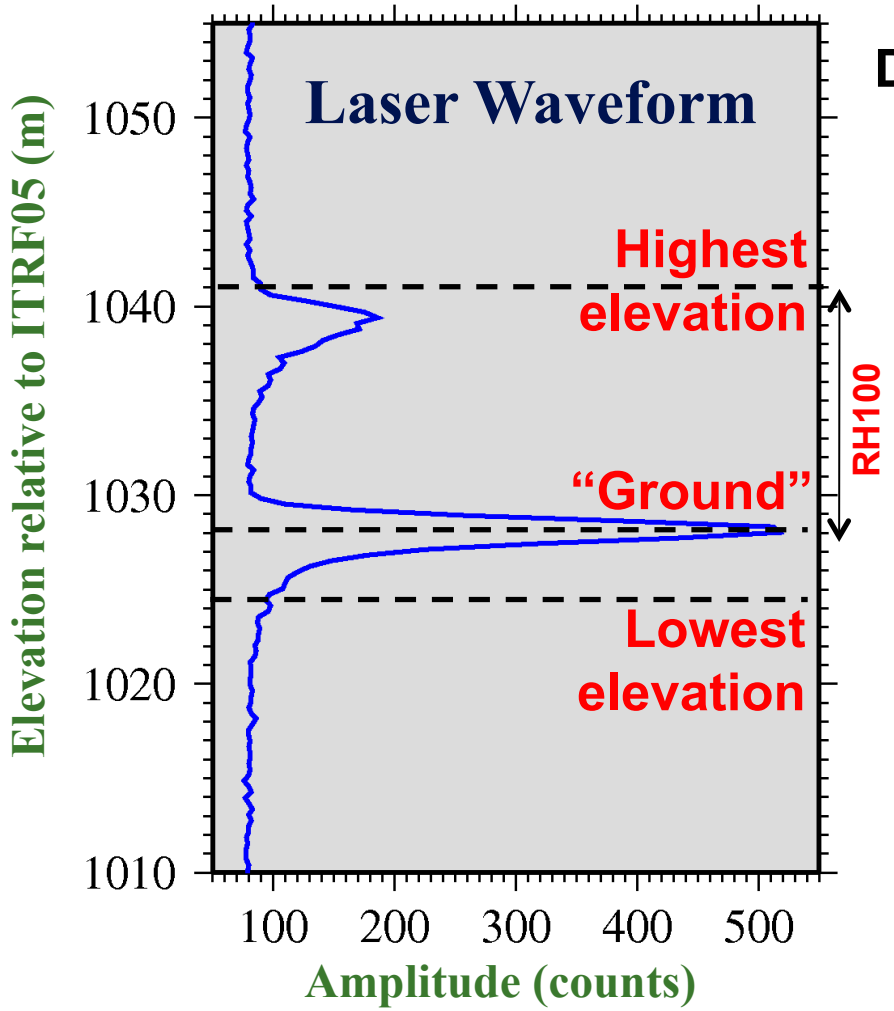


LVIS Lidar Remote Sensing of Greenland, 2009

- **In April 2009, LVIS imaged areas of Greenland for IceBridge**
  - **3 x ~8-hr flights in NASA P-3B aircraft**
  - **Based out of Thule**
  - **~25m wide footprints, 1.5-2km swath**
  - **Altitude: 25,000-27,000'**
  - **~30 million waveforms collected**

- **LVIS Lidar accurately maps surface topography and measures surface vertical and spatial structure across multiple scales**
- **The data form the basis for future repeat surveys of the ice sheet and its margins from aircraft during the data gap between the current orbital ICESat and future lidar missions.**

LVIS Measurement Process



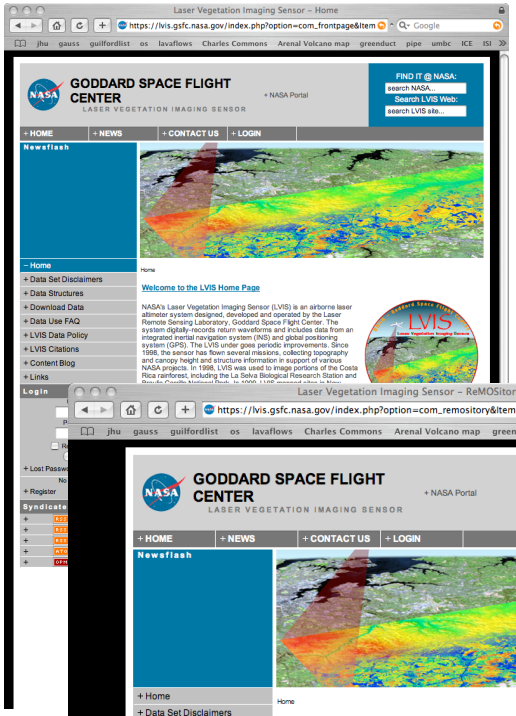
Data products include:

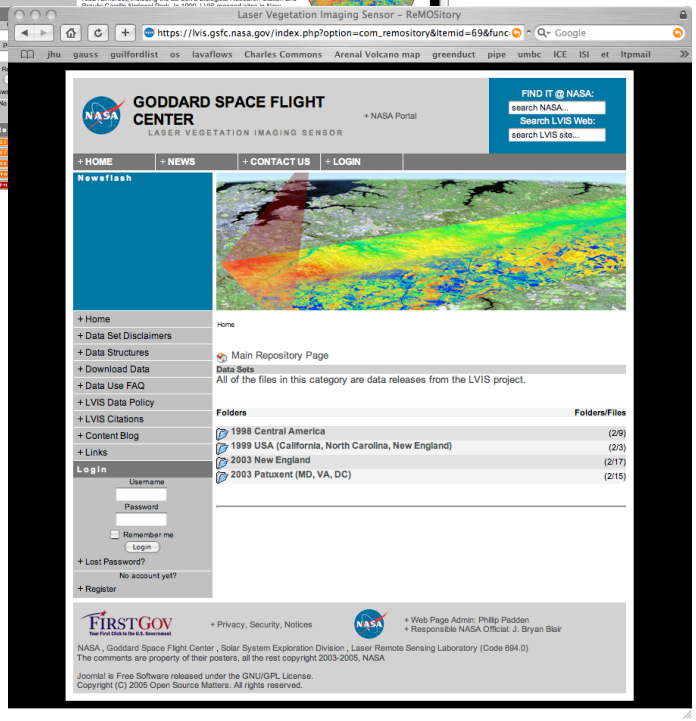
- **"Ground" elevation: *zg* (elevation using center of lowest mode)**
- **Elevation of highest reflection: *zt***
- **Vertical distribution of intercepted surfaces (waveform).**
- **Vertical extent (e.g., feature depth or height): RH100**
- **Energy quartiles (RH25/50/75)**
- **Other products ?:**
  - **-waveform centroid**
  - **-ICESat**

Data available at https://lvis.gsfc.nasa.gov

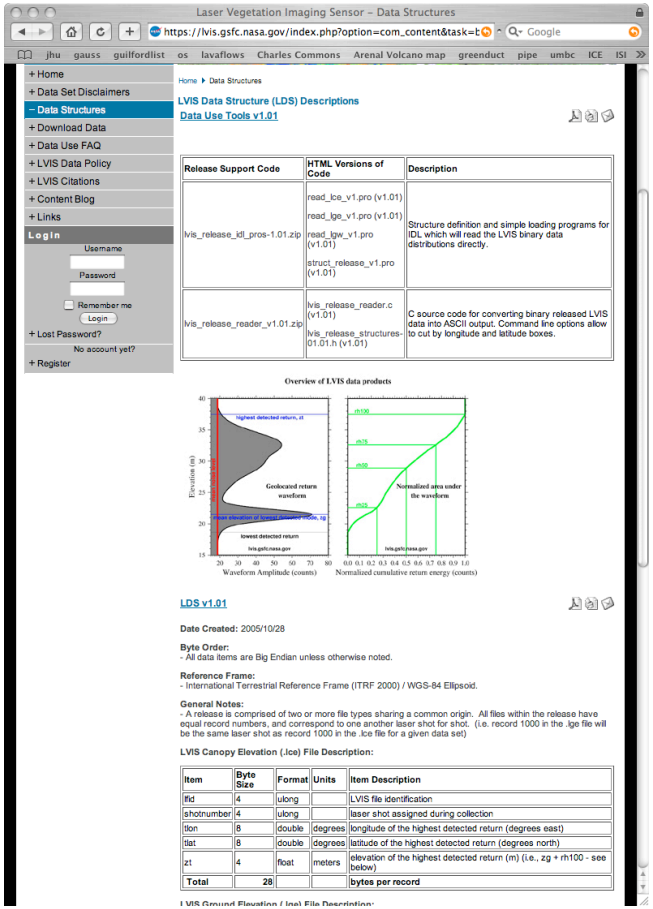
- The waveform represents the entire time history of interaction between the laser pulse and the surface of the Earth.
- Allows extraction of multiple data products, and to apply, reapply algorithms.

LVIS Data Available Online





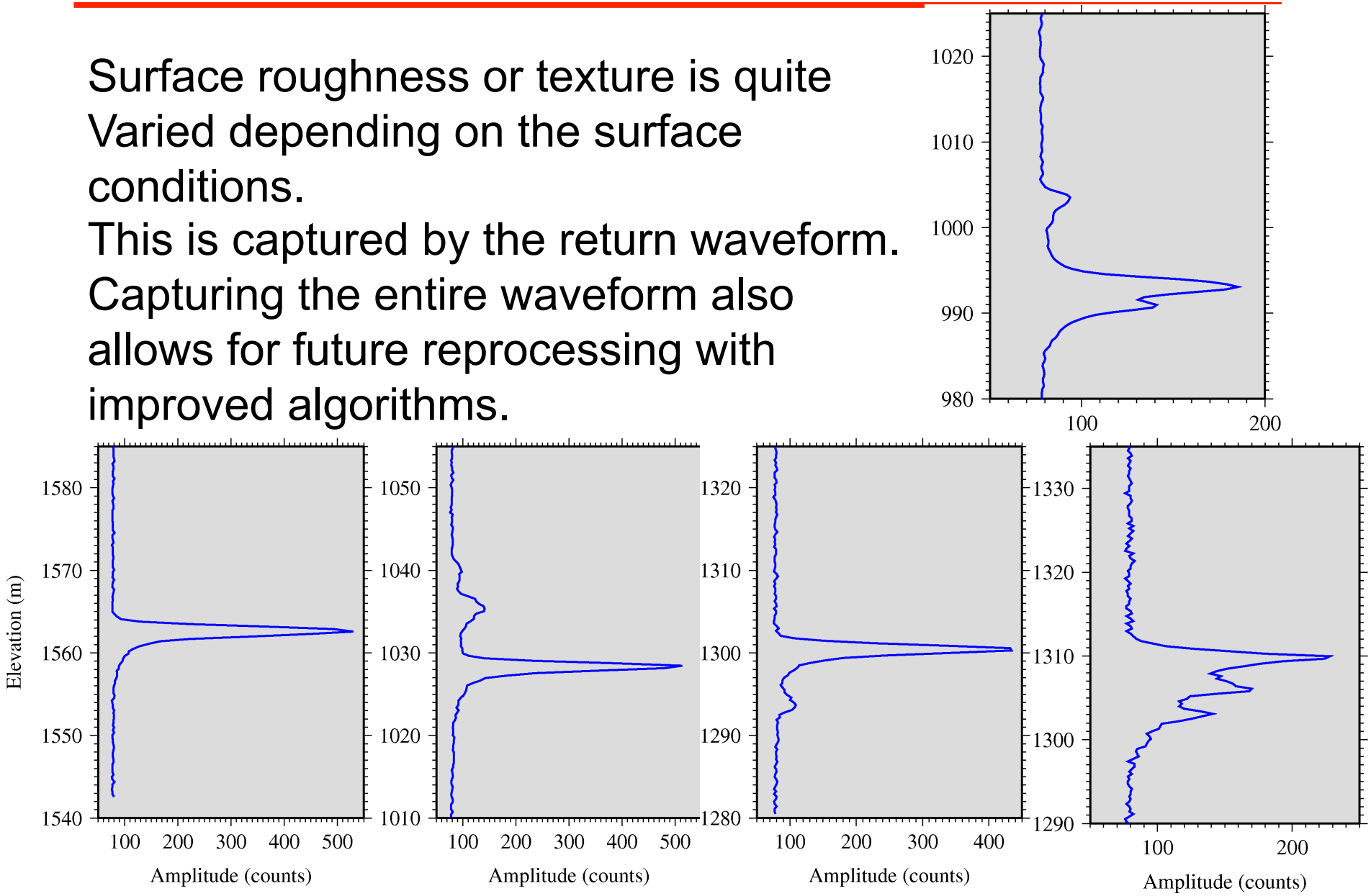
- **LVIS data products are available to download from https://lvis.gsfc.nasa.gov**
- **Currently >500 registered users worldwide**
- **Latest data products distributed online as they become available**



- Web site also contains useful information on using LVIS data
- Users can ask LVIS-specific questions if they have problems
- Frequently-updated FAQ section

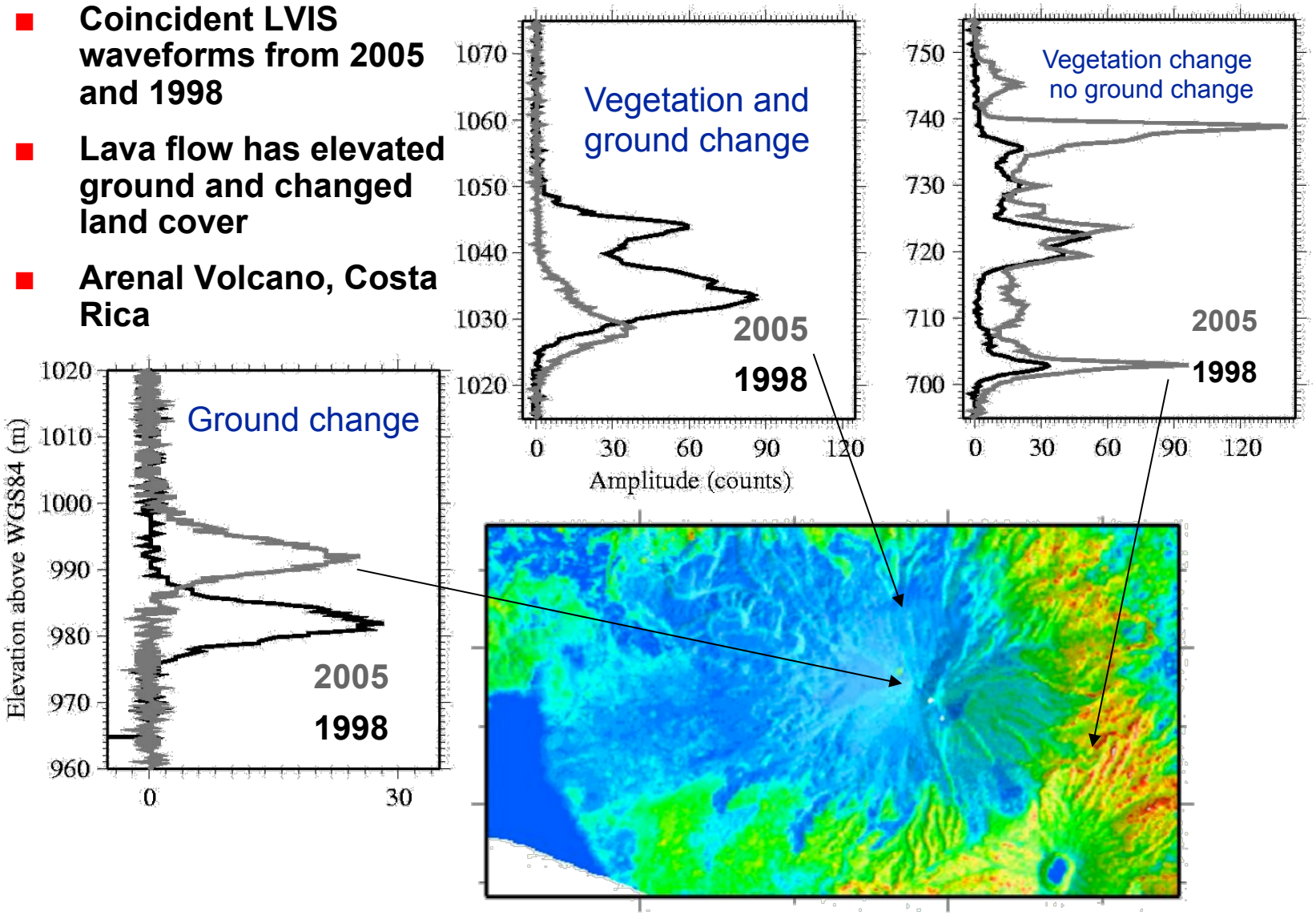
Example Ice Waveforms

Surface roughness or texture is quite Varied depending on the surface conditions.
This is captured by the return waveform.
Capturing the entire waveform also allows for future reprocessing with improved algorithms.



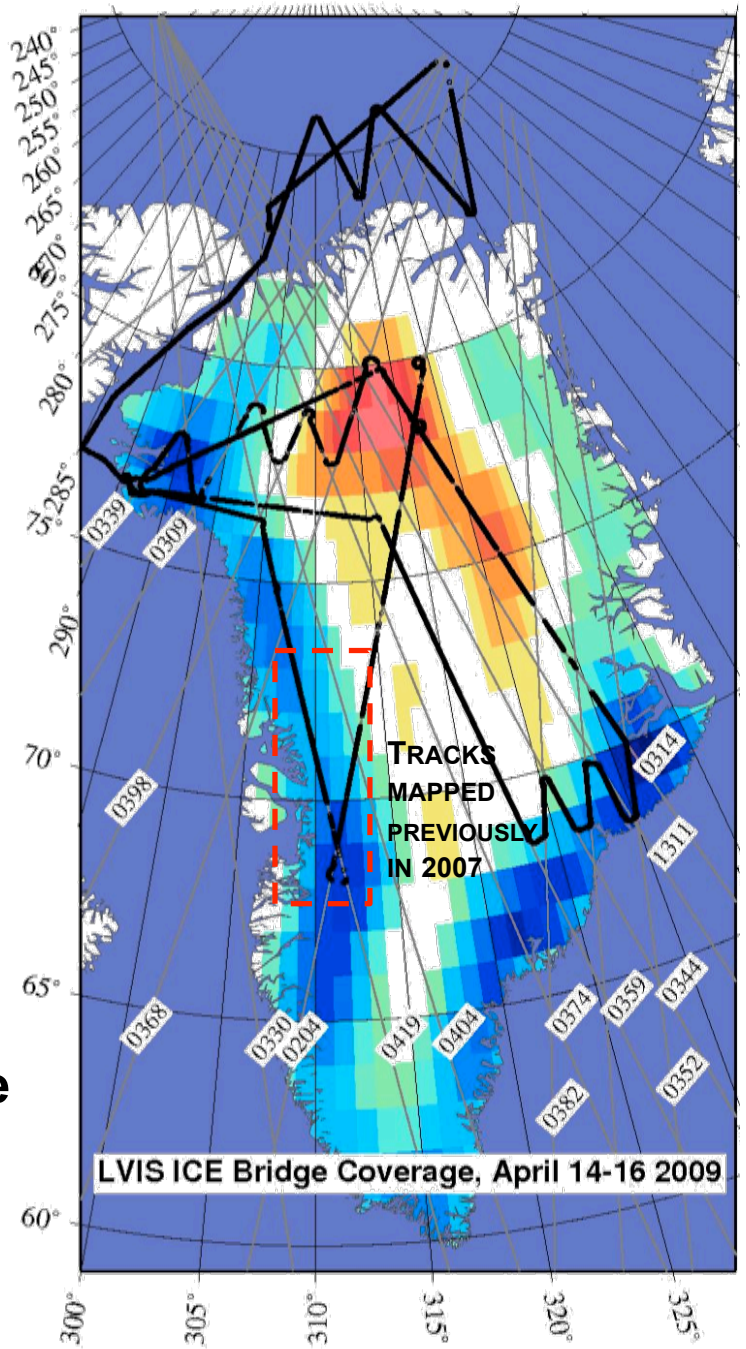
Change Detection with Waveforms

- **Coincident LVIS waveforms from 2005 and 1998**
- **Lava flow has elevated ground and changed land cover**
- **Arenal Volcano, Costa Rica**



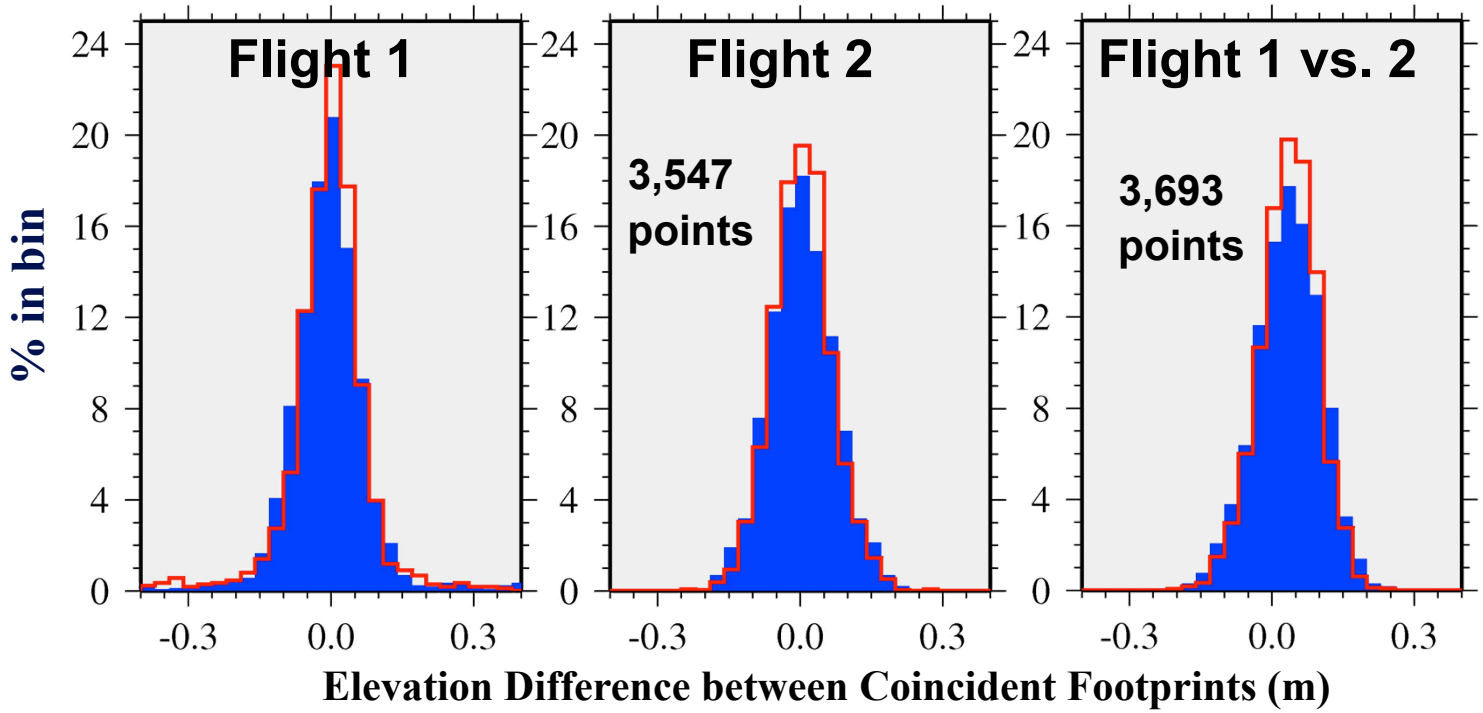
Data collected in Greenland in 2009

- ~9,500 lineal km of ICEsat tracks imaged, including 1,500 lineal km imaged previously using LVIS in 2007.
- Flights timed with ICESat overpass to minimizing biases due to change
- LVIS swaths cover a wide variety of terrain, change regime areas, and include ATM profiles
- The LVIS data set provides a consistent datum to enable inter-mission calibration and validation, and assist in the separation of inter-mission observational system biases and errors from true decadal and seasonal surface elevation change.



Data Precision, Greenland 2009

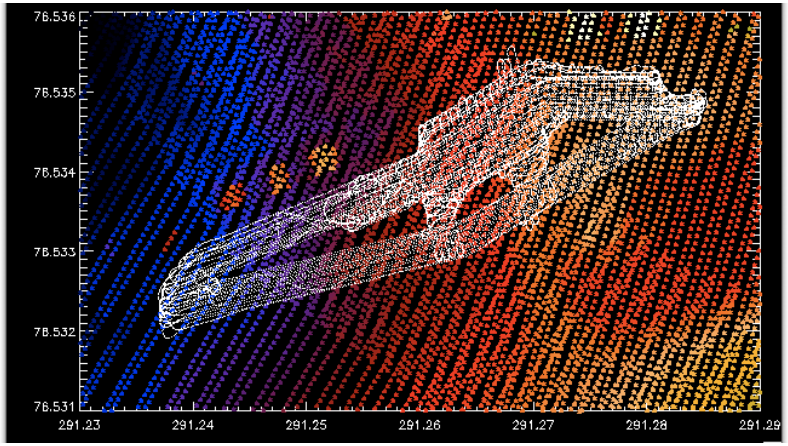
- Compare coincident LVIS data to assess data precision
  - Footprint centers < 1m of each other



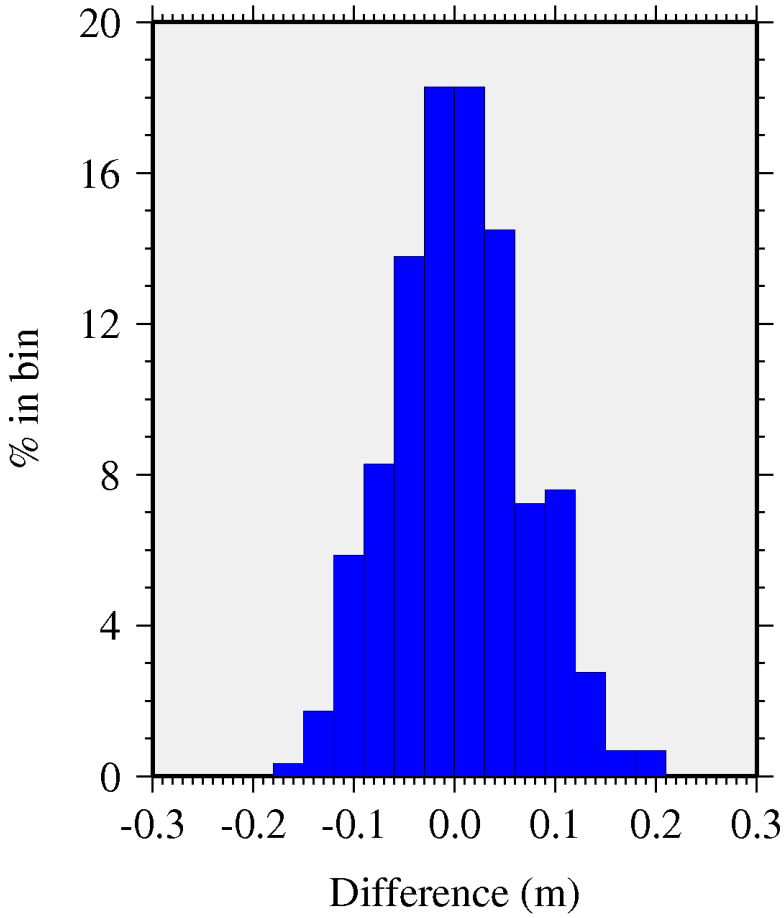
Flight	#1	#2	#1 vs #2
Mean difference (m)	0.00	0.00	0.02
Standard deviation (m)	0.06	0.07	0.07

Data Accuracy, Greenland 2009

- Using differential kinematic GPS data from Thule ramp
  - Courtesy of E. Frederick (NASA ATM)
- LVIS elevations compared to closest GPS measurement
- 290 comparison points
- Standard deviation (1σ) = 0.065 m

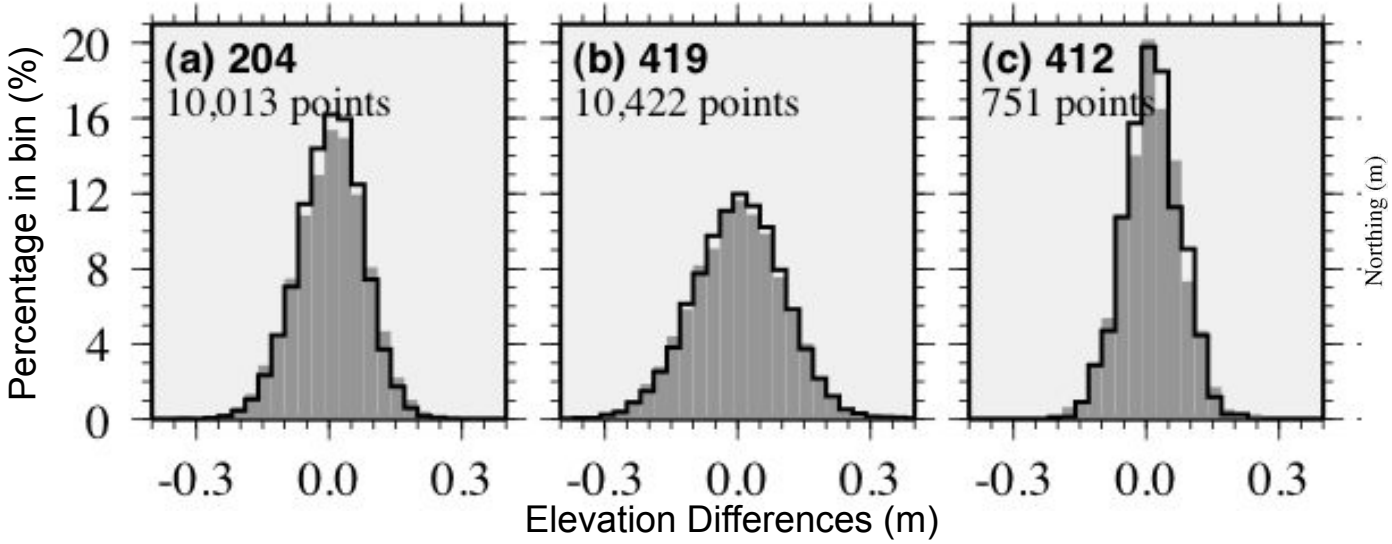


LVIS minus Ground GPS (m)

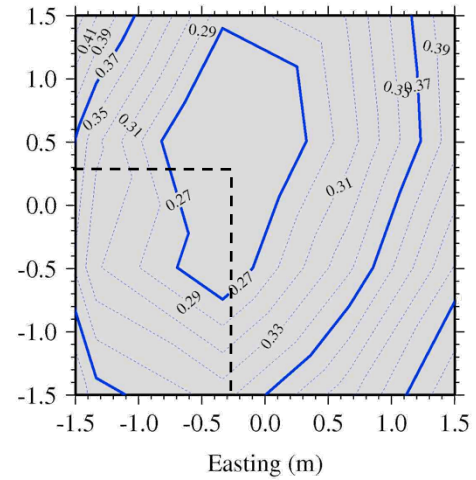


LVIS Performance in Greenland, 2007

Histograms of elevation differences at coincident LVIS footprints:

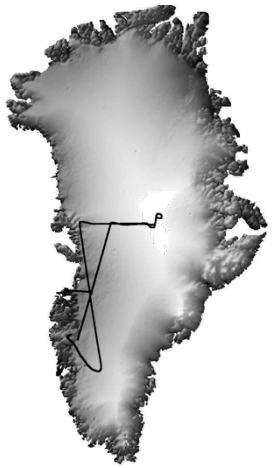


Horizontal Positioning Accuracy:



Mean difference	**0.00 m**	**0.00 m**	**0.01 m**
Standard deviation (1σ)	**0.08 m**	**0.11 m**	**0.06 m**

Small footprint and LVIS data positioned within 0.4m

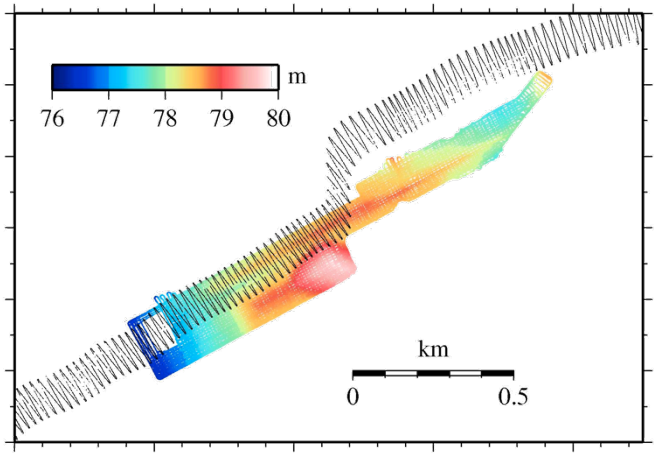


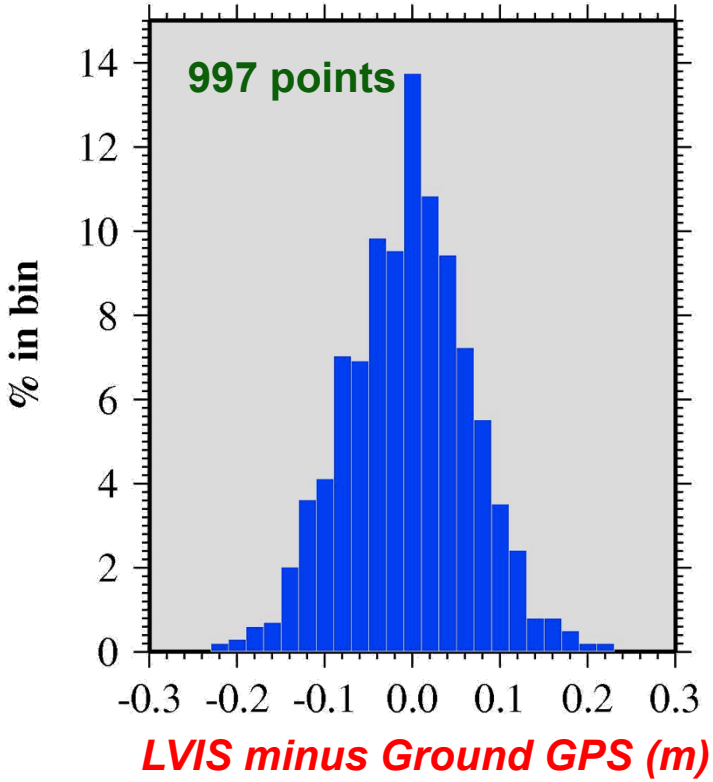
- LVIS data collected on 9/20/07 and 9/21/07 from ~27,000' in P3-B.
- Two ~850km long transects over ice sheet plus ~35 km long transect in the Summit area.
- Elevations differences between coincident footprints used to evaluate system performance.

From: Hofton et al. (2008), Geophysical Research Letters, DOI:10.1029/2008GL035774

Waveform Lidar Elevation Accuracy, 2007

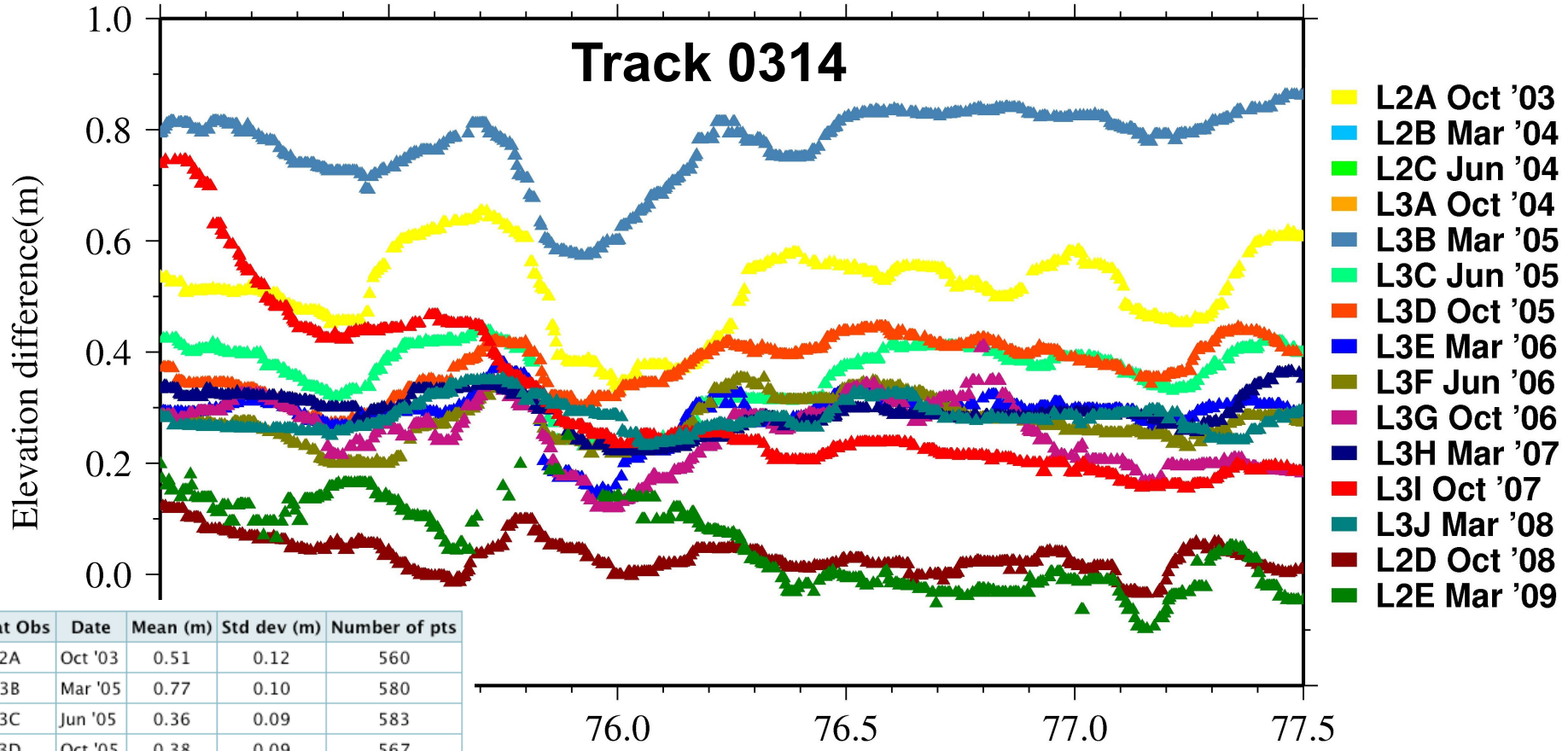
- Using differential kinematic GPS data from Sondrestrom (Kangerlussuaq) runway and ramp area
  - Courtesy E. Frederick (NASA ATM)
- Single overflight on 9/20/07
- LVIS elevations compared to closest GPS measurement





Standard deviation (1σ): **0.07 m**

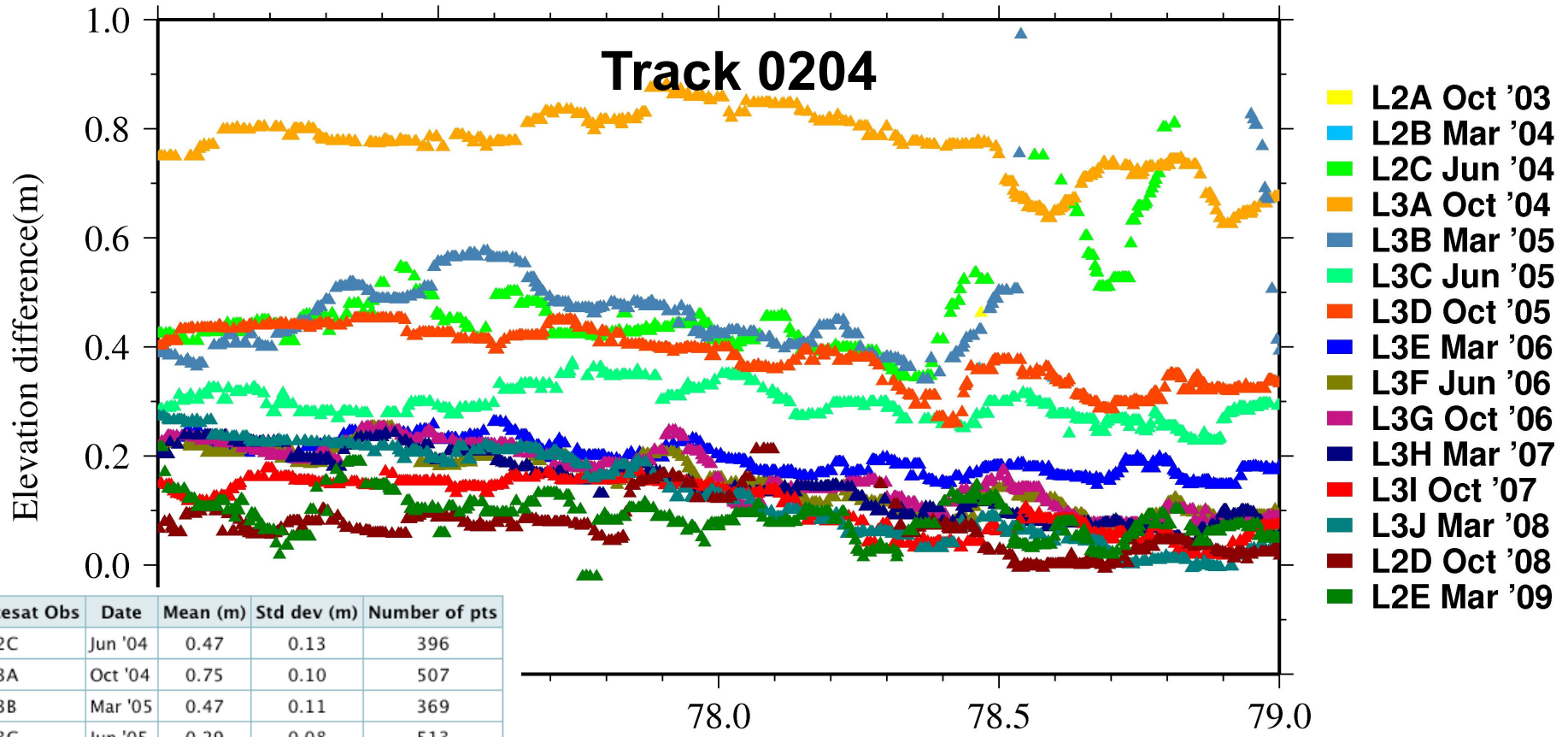
2009 LVIS: Comparison to ICESAT



Icesat Obs	Date	Mean (m)	Std dev (m)	Number of pts
L2A	Oct '03	0.51	0.12	560
L3B	Mar '05	0.77	0.10	580
L3C	Jun '05	0.36	0.09	583
L3D	Oct '05	0.38	0.09	567
L3E	Mar '06	0.29	0.06	570
L3F	Jun '06	0.27	0.08	578
L3G	Oct '06	0.24	0.10	539
L3H	Mar '07	0.29	0.07	556
L3I	Oct '07	0.22	0.08	401
L3J	Mar '08	0.28	0.07	543
L2D	Oct '08	0.03	0.08	530
L2E	Mar '09	0.04	0.18	506

- Elevations of ICESat and LVIS footprints compared (<3m)
- Track 0314, from 75N to 77.5N.
- Vertical offsets between ICESat observation periods
- ICESat and LVIS data typically agree to <9cm (1σ)

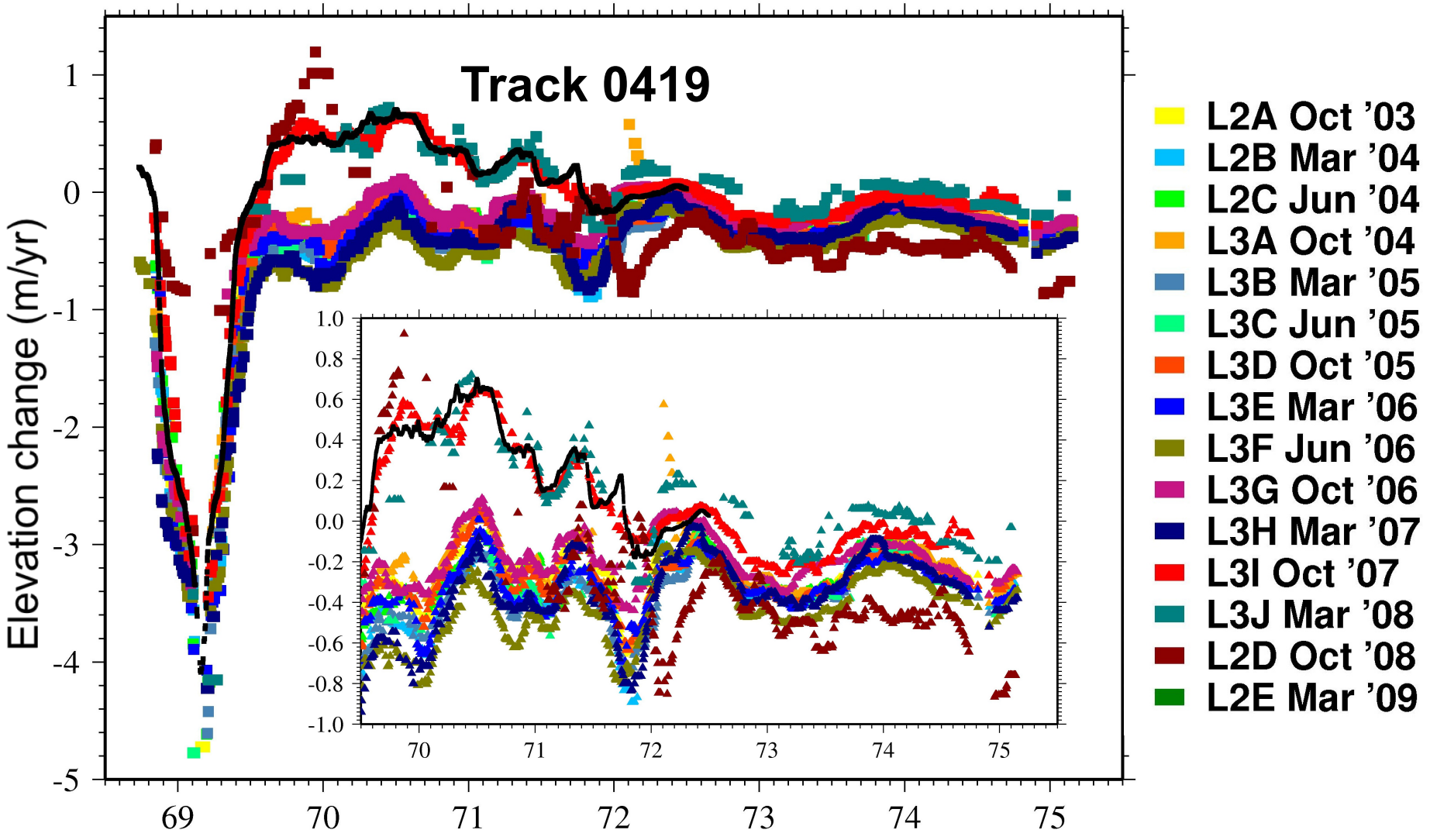
2009 LVIS: Comparison to ICESat



Icesat Obs	Date	Mean (m)	Std dev (m)	Number of pts
L2C	Jun '04	0.47	0.13	396
L3A	Oct '04	0.75	0.10	507
L3B	Mar '05	0.47	0.11	369
L3C	Jun '05	0.29	0.08	513
L3D	Oct '05	0.37	0.09	564
L3E	Mar '06	0.19	0.09	573
L3F	Jun '06	0.15	0.08	543
L3G	Oct '06	0.15	0.09	561
L3H	Mar '07	0.13	0.09	503
L3I	Oct '07	0.10	0.08	537
L3J	Mar '08	0.12	0.10	541
L2D	Oct '08	0.06	0.09	537
L2E	Mar '09	0.08	0.14	547

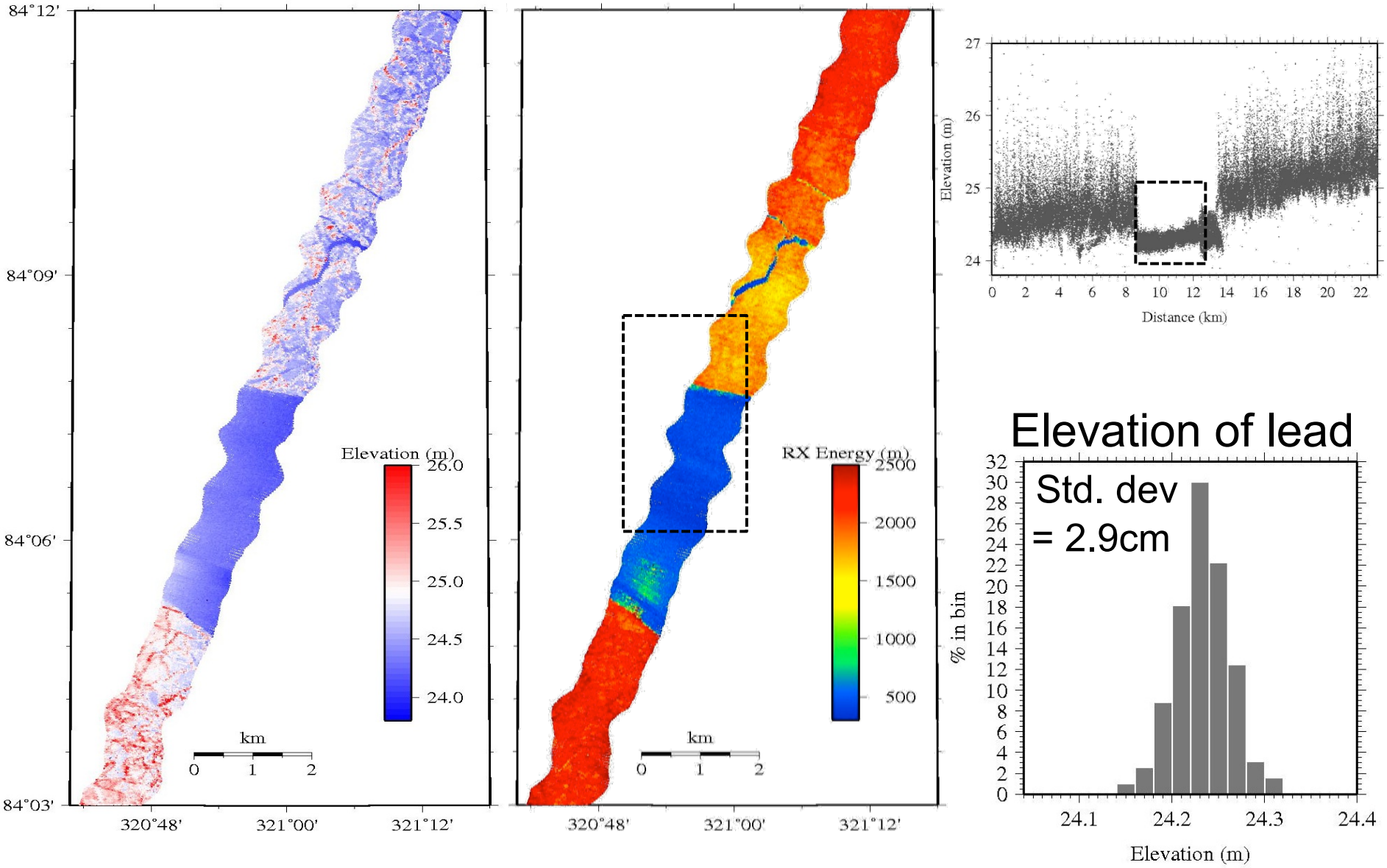
- Elevations of ICESat and LVIS footprints compared (<3m)
- Track 0204, from 77.5N to 79N
- Vertical offsets between ICESat observation periods
- ICESat and LVIS data typically agree to <9cm (1σ)

2009 LVIS: Comparison to ICESat



- **Elevation change LVIS 2009 to Icesat**

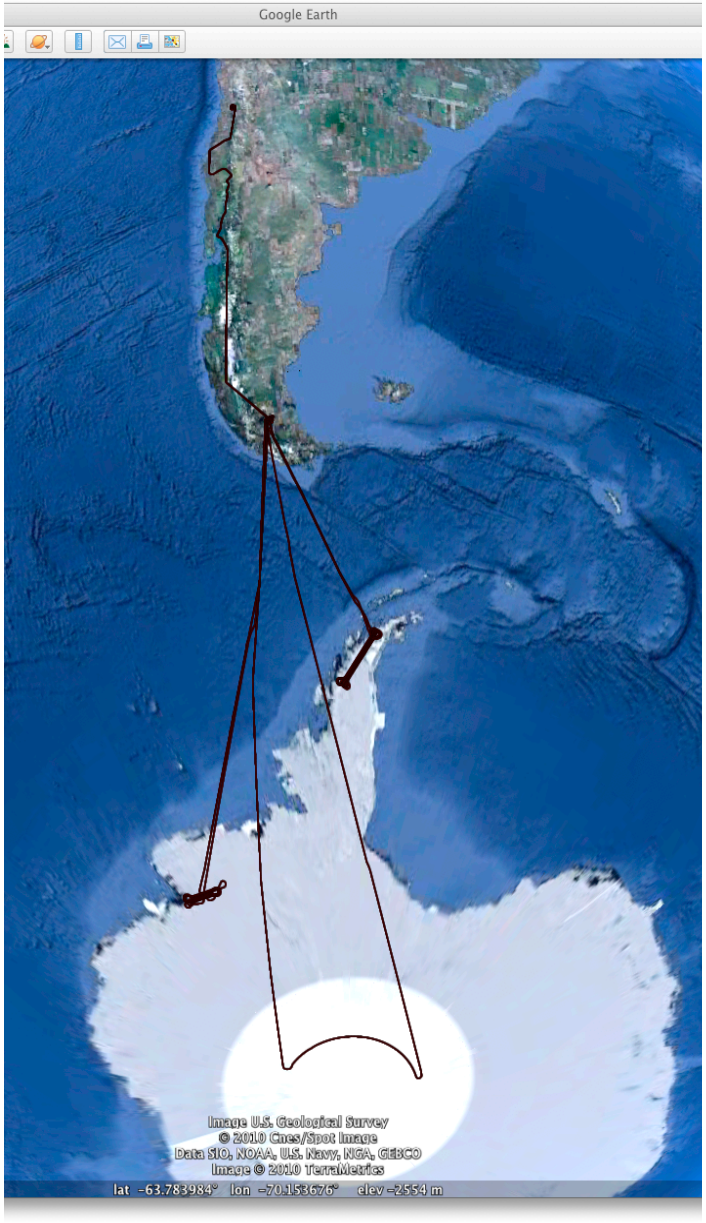
LVIS Northern Sea Ice Flight April 16 2009

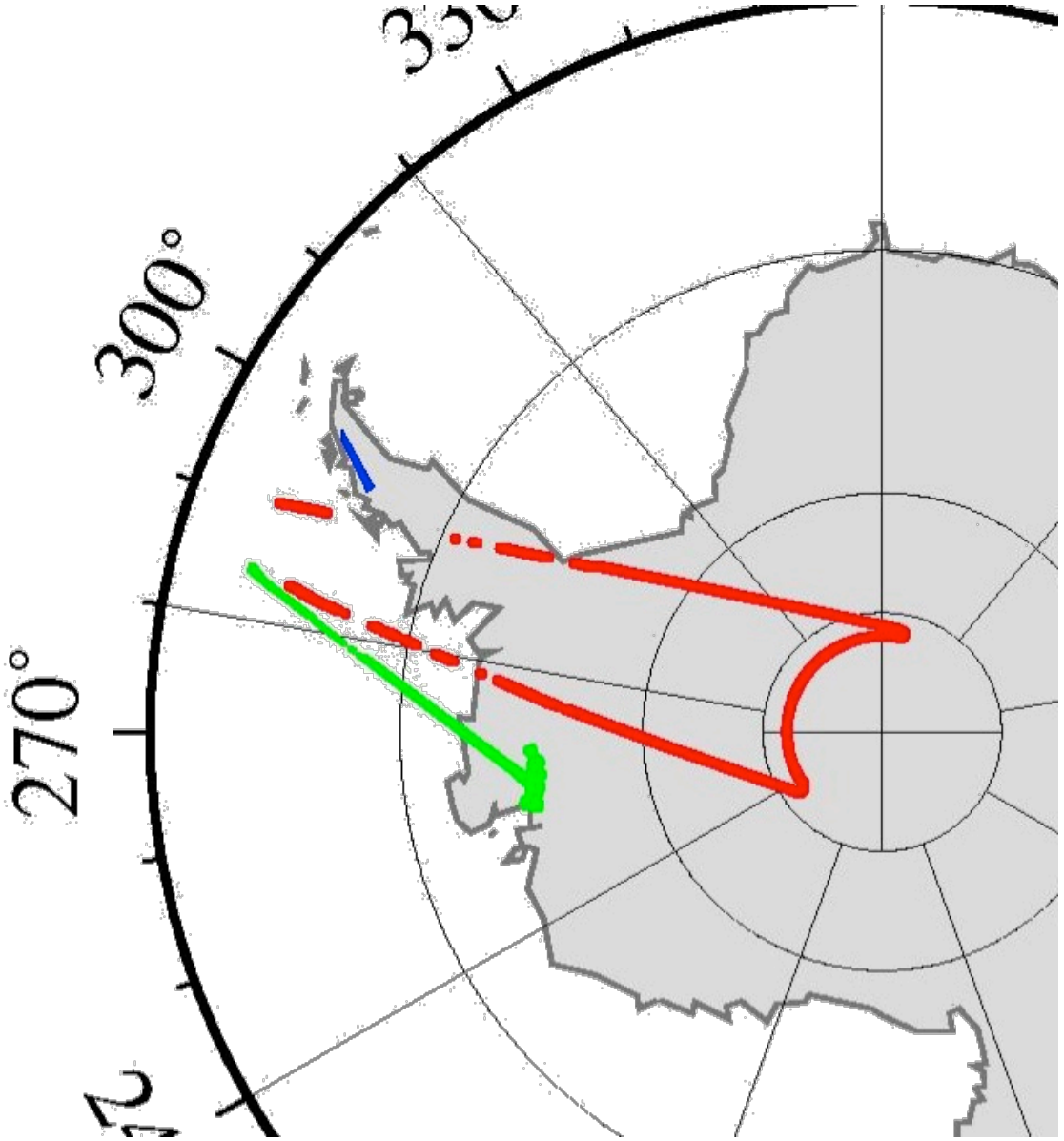


Status of Greenland 2009 Data

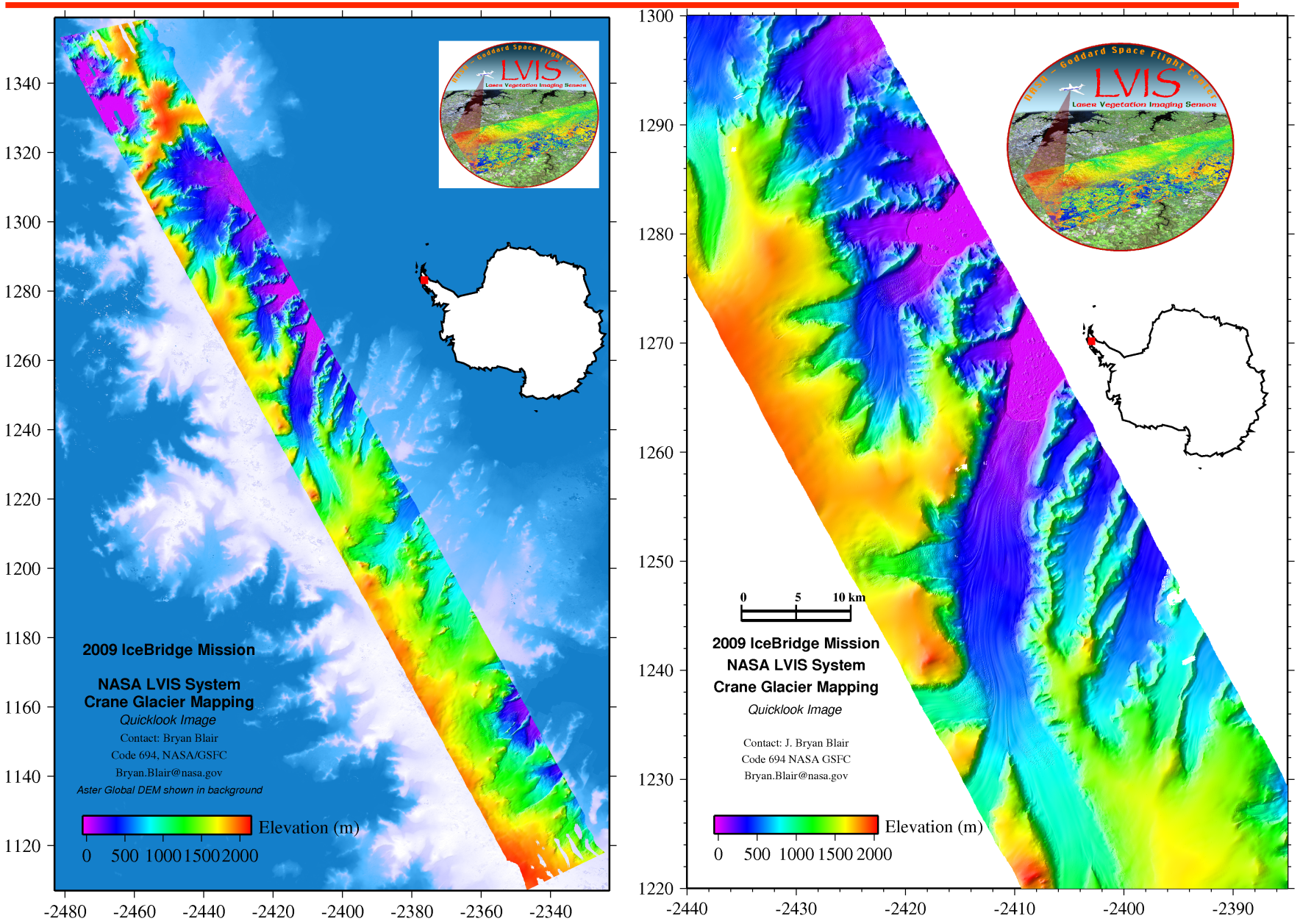
- 3 LVIS flights: 2 land ice and 1 sea ice
- ~9 million waveforms (after quality checks) collected on each flight (~30 million total)
- Data processing completed on land ice flights and data released on lvis web site.
- Preliminary processing only on sea ice flight – problem due to power supply failure on LVIS Applanix 510. Data quality reduced. Some success using separate data segments (before and after Applanix dropout). Attempting to use Ames Applanix 610 data but unit was mounted several meters away on ATM – long lever arm and potential airframe flexing will result in some degradation in performance.
- Expect to release preliminary sea ice data by next week.

LVIS Flights Antarctica 2009

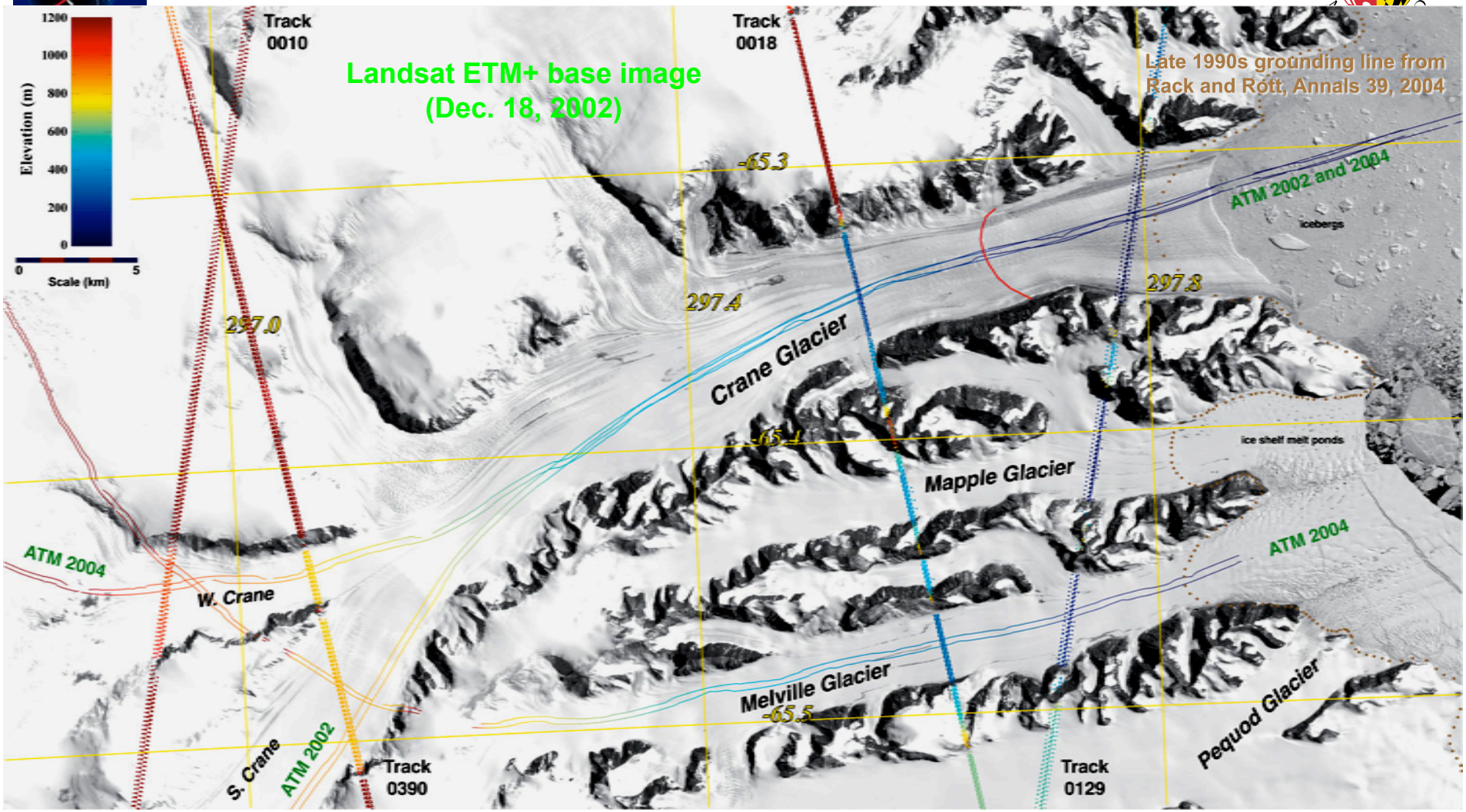




LVIS Peninsula Flight – Crane Glacier



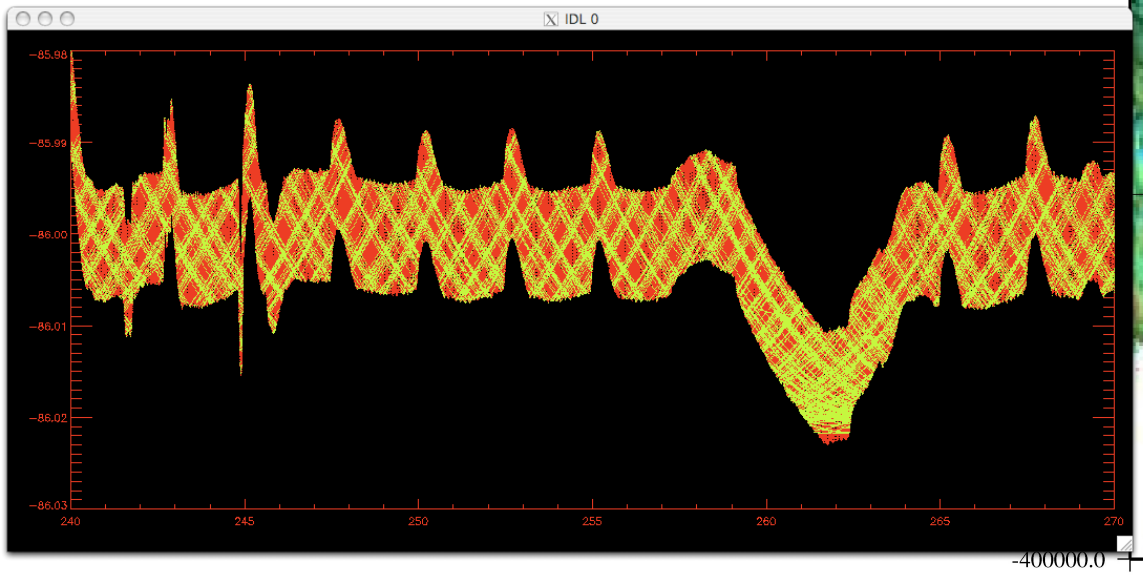
Crane Glacier from ICESat and ATM data



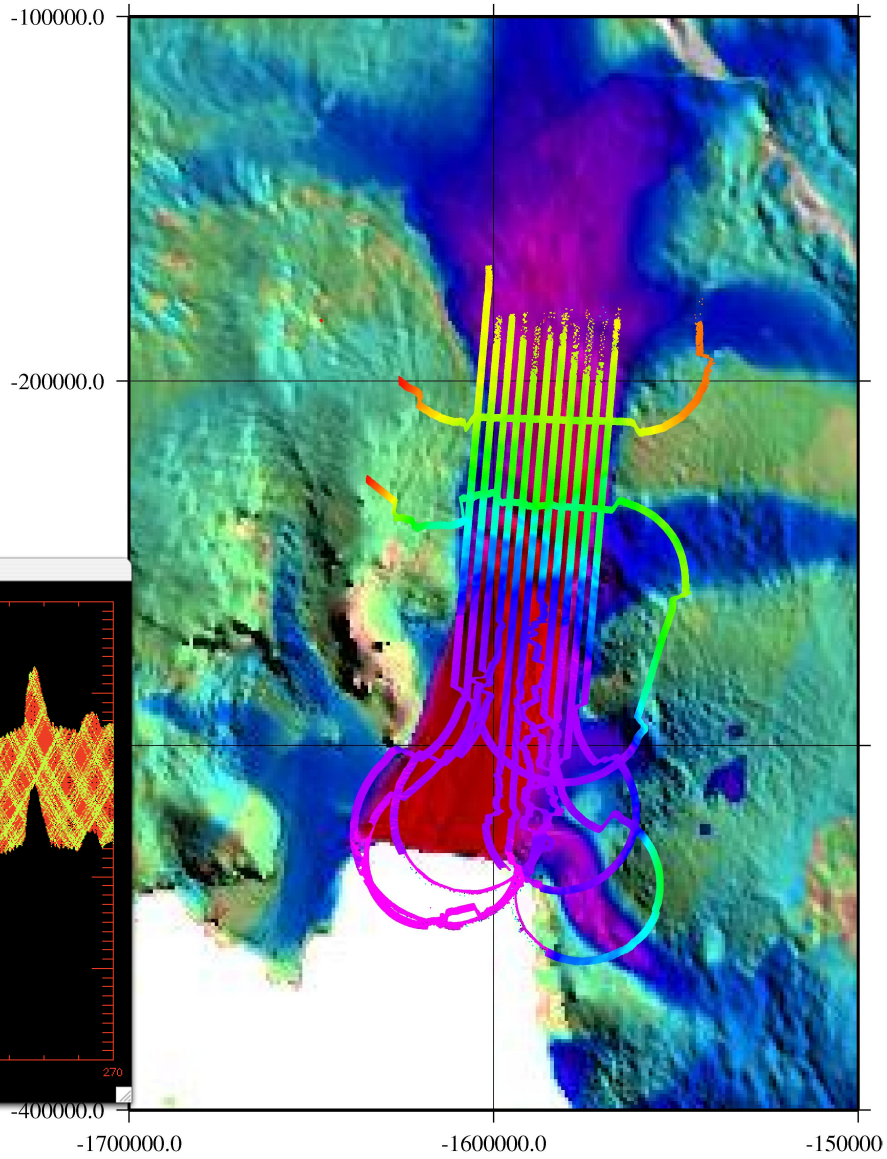
Four ICESat-1 profiles cross the Crane Glacier and intersect with ATM 'along-flow' profiles that were initially taken in late 2002 and 2004. Those intersections have enabled the timing of elevation changes at those locations to be determined. Note, Track 0129 now crosses the Crane Fjord which once contained ice >700 m thick. Based on the Nov. 2009 ice edge (red curve) and the late 1990s grounding line, the Lower Crane (fjord) has lost ~20 cubic km of ice.

Pine Island and Pole Hole

- Pole Hole Flight covered ~100% of desired area (good weather call Seelye) and sampled ~half a million ICESat footprints. ~40% of all ICESat data orbits.
- Some Pine Island data losses inland due to clouds.

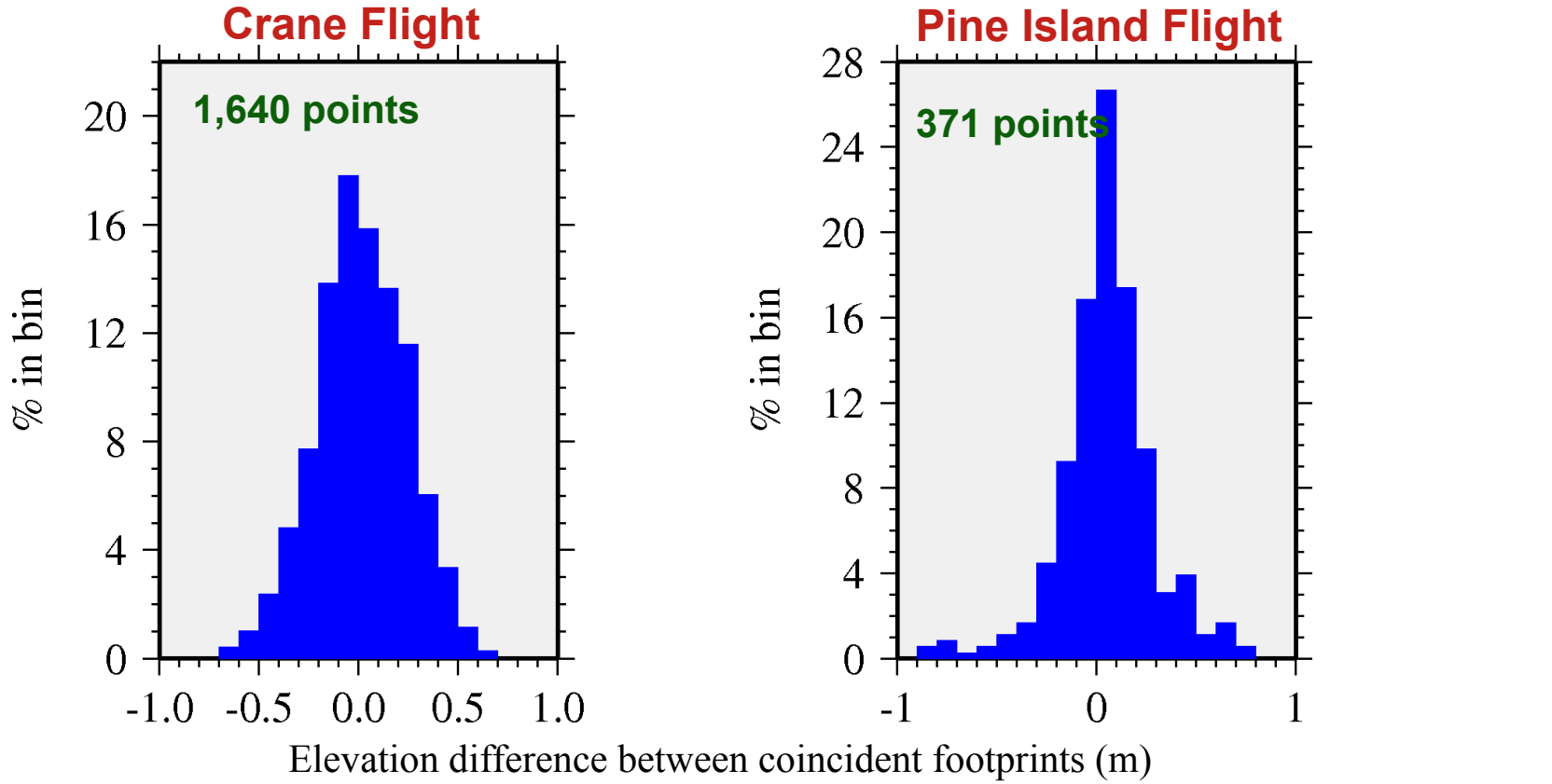


Pine Island Flight



Preliminary Data Precision, Antarctica 2009

- **Assessing elevation differences between coincident LVIS footprints**



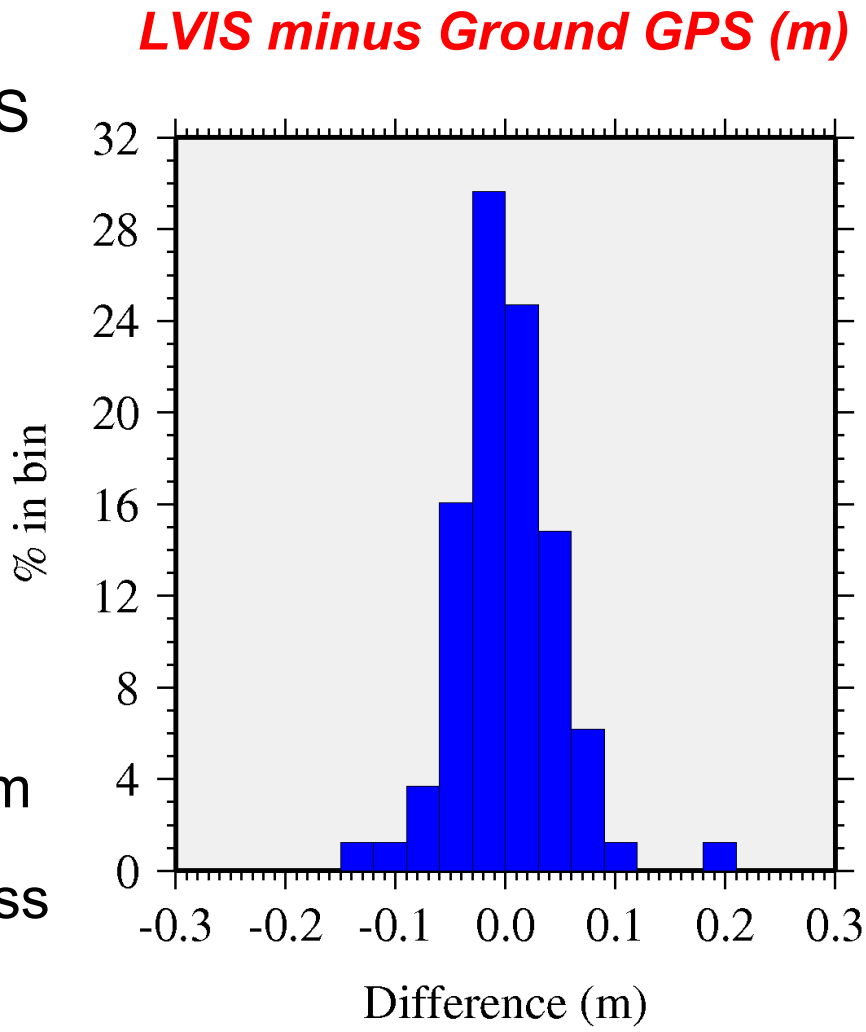
Mean difference:	**0.01m**
Standard deviation (1σ):	**0.23m**

Mean difference:	**0.05m**
Standard deviation (1σ):	**0.15m**

- **Note: These preliminary results use an initial (intermediate) parameter solution based on PPP trajectories (i.e., no base stations) and preliminary waveform processing.**

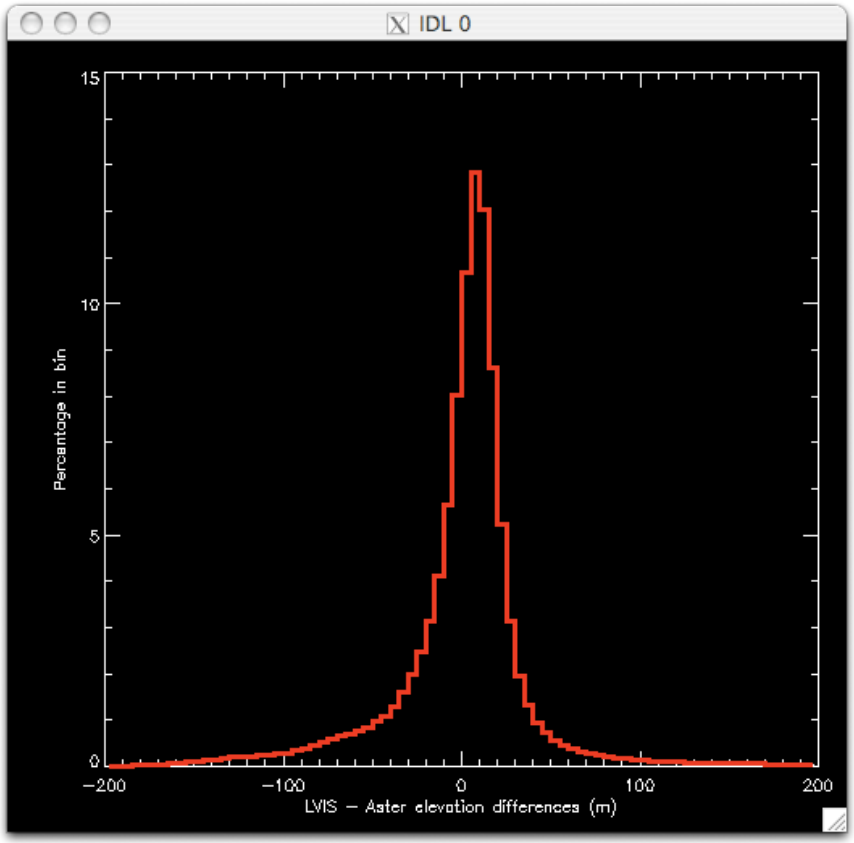
Preliminary Data Accuracy, Antarctica 2009

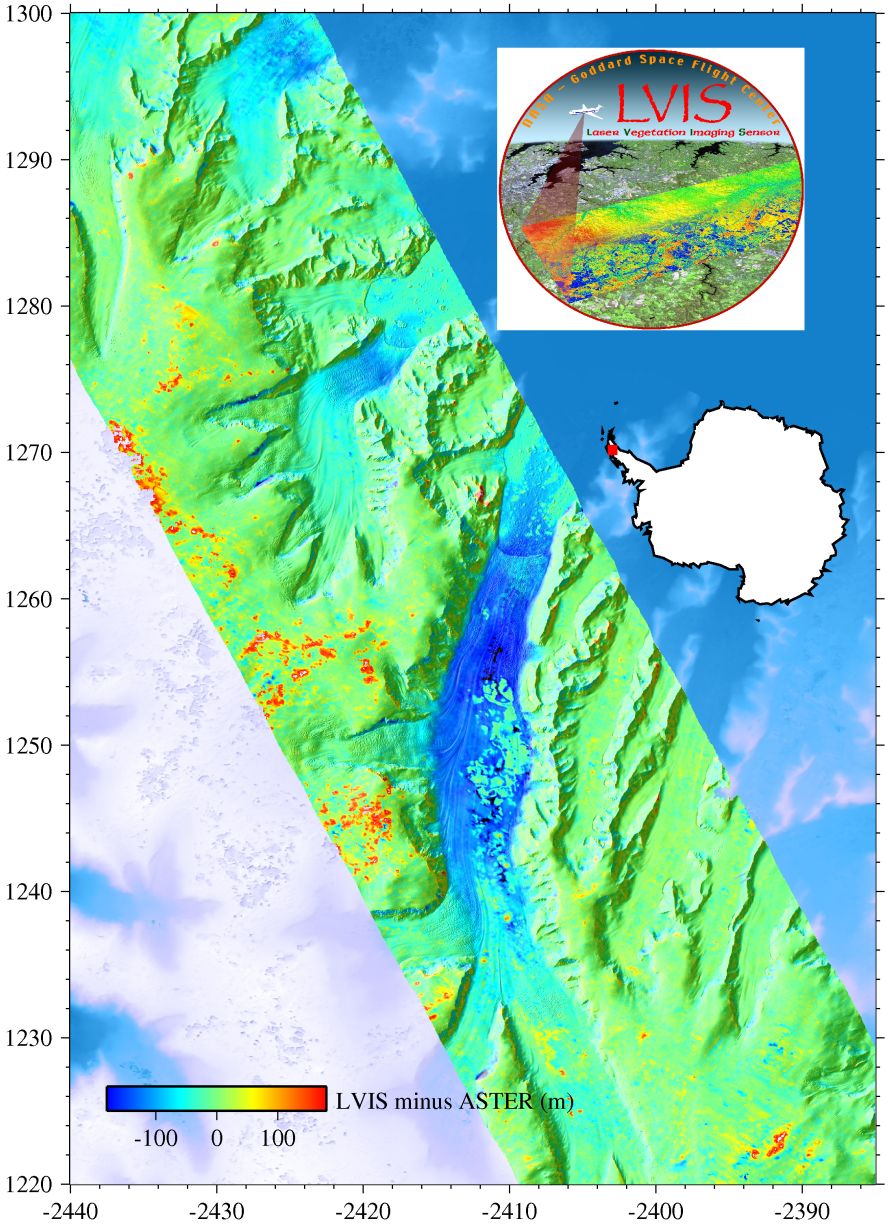
- Using differential kinematic GPS data from Punta Arenas airport parking lot
- LVIS elevations compared to closest GPS measurement
- 82 comparison points
- Mean = 0.003m
- Standard deviation (1σ) = 0.04m
- Only Crane flight calibration pass has been analyzed so far.



Comparison to Aster

- **LVIS minus ASTER Global DEM over Crane Glacier**

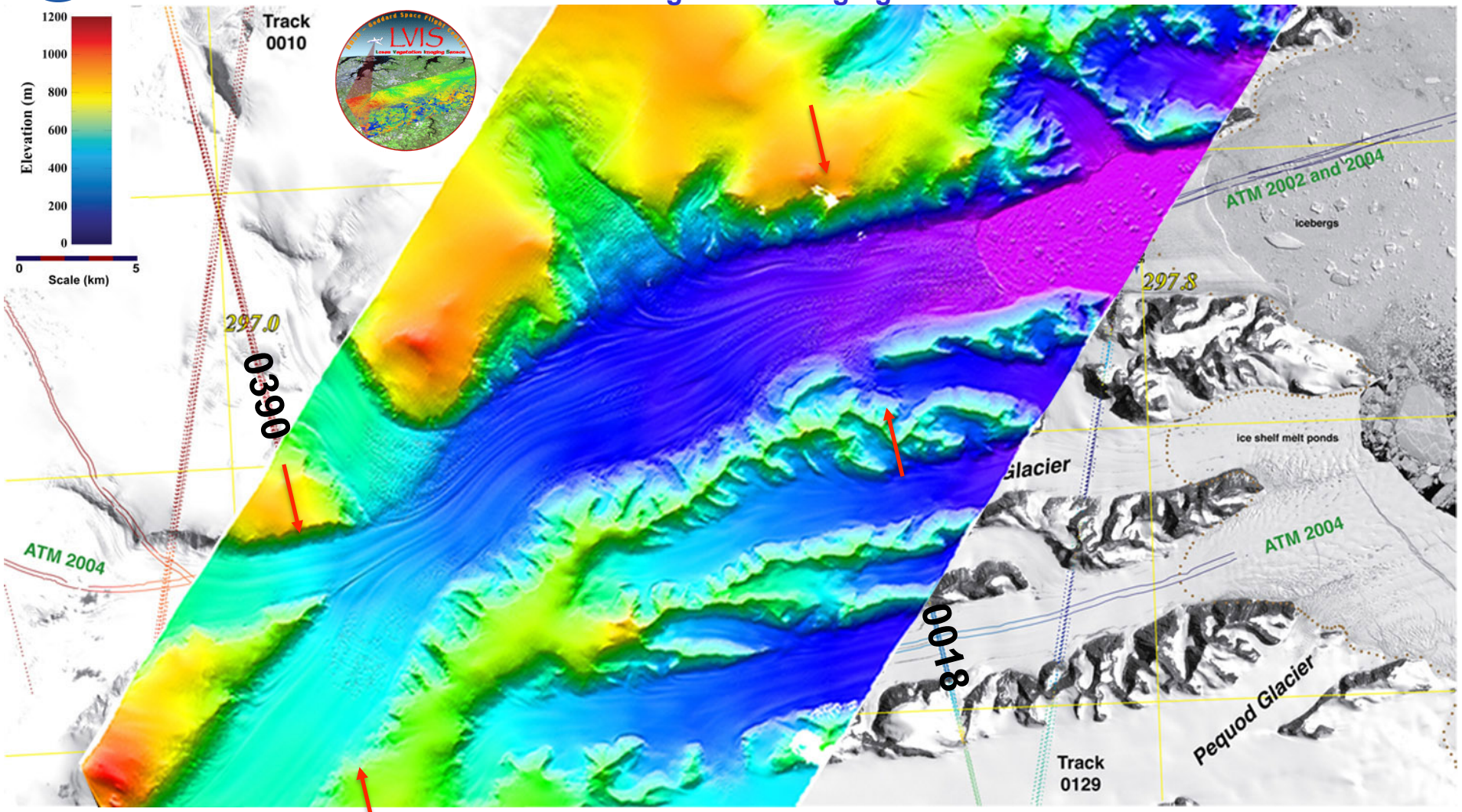




Crane Glacier from LVIS 2009 ICE Bridge Data

LVIS = Land Vegetation Imaging Sensor

GEST Goddard Earth Sciences and Technology Center



Contact: J. Bryan Blair Code 694 NASA GSFC
Bryan.Blair@nasa.gov

Elevation (m)

500 1000 1500 2000

A small portion of the area that LVIS on the NASA DC-8 mapped in >7.5 hours on 11/5/2009. The entire image is 26 x 260 km (~16 x 160 miles). The total area is ~7,000 sq. km - this is the largest, contiguous area ever mapped with LVIS, 16 lines stitched together ("mowing the lawn") and the footprints are ~20 m in diameter spread across ~2 km wide swaths, and the DC-8 did it in one flight.

https://lvis.gsfc.nasa.gov/index.php

Status of LVIS Antarctic 2009 Data

- **No funding for processing these data has been received.**
  - **Lack of stable funding prevents us from hiring – small team has conflicts between deployments and data processing, and other research.**
- **After funding is received we should be able to release a 1st draft DEM of the Antarctic Peninsula data in weeks.**
- **Other 2 high-altitude LVIS flights (Pine Island, Pole Hole)**
  - **Beginning work on better quality GPS trajectories**
  - **GPS/Gyro lever arm calculations in process**
- **Work to incorporate Applanix 610 data has not yet begun**
  - **Should result in ~2X better accuracy over sloped terrain.**
- **Collaborating with UNAVCO and NSIDC on LVIS data formats - LVIS/ICESat data proposal funded.**